socket shoulder joint capable of such varied and extensive motion, with a high degree of pronation and supination of the fore arm, and last, but not least, the wonderfully specialized hand with its thumb opposable to each of the four digits.

After this brief survey, and with the forementioned proposition in view, viz., the correlation existing between the development of the clavicle and the work done by the fore limbs, we are left to draw the rational conclusion that the subject under consideration is one of *use* and *disuse* of parts, as Darwin has so clearly pointed out in his chapter on rudimentary organs in the Origin of Species. The facts we have noted in our hasty glance at the Mammalia confirm this, in the more or less perfect development of clavicles in arboreal, fossorial, aërial and all other forms where the fore limbs are the active, aggressive pair in the life of the animal, and their absence or rudimentary condition in the hoofed animals, the marine species and all others where the anterior pair take a secondary place in the work done by the limbs.

As there is, of course, no actual disuse of a part as a whole (the nearest approach to this being in marine forms), a simple, uncomplicated motion existing, with little strain at the shoulder joint, the parts require less support and fewer points for ligamentous and muscular attachment than where the movements are more complicated and the strain more severe. Consequently we have a greater or less differentiation in the elements of the shoulder girdle as the case may be, and the clavicle, holding as it does a position of secondary importance, is the unstable, variable element.

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PEAR BLIGHT AND ITS CAUSE.

BY J. C. ARTHUR.

PEAR trees in this country are subject to an endemic disease that, owing to its malignancy and frequent occurrence, is well known to cultivators and fairly well discriminated by them. It is known both as *pear blight* and *fire blight*, and the same disease in the apple and quince is also called *twig blight*. The term blight is applied to many kinds of plant diseases, and especially to those that eventually kill without rendering the cause conspicuous; it is also the name of a class of disease-producing fungi. The pear malady bearing this name is, however, a specific disease, although

it would be a matter of considerable difficulty to describe it in such diagnostic terms that the reader would recognize it under all conditions and avoid confounding it with the numerous other blights and incidental maladies which resemble it. Its most characteristic feature, if one considers only pomaceous trees, such as the pear, apple, quince, crab, hawthorn, etc., is the complete dying of the branches subsequent to the appearance of the foliage without obvious cause and usually with apparent suddenness. This involves the limb and its leaves, both of which turn blackish and usually exhale a peculiar but not very strong odor. From the softer stems there often exudes a viscid, whitish substance forming small drops on the surface of the bark and finally becoming hard like an exudation of gum.

The blackening of the dying branches does not differ from that produced by death from other causes; hence arises the danger of mistaking other injuries of the tree for the true blight as here understood. Death may be brought about by the limb being partly broken off, or it may be punctured and killed by the pear-blight beetle (*Xyleborus pyri*), a very small insect which often escapes detection, or it may result from other mechanical injuries. There is also the blackening of the ends of young twigs in spring known as frozen-sap blight, the blackening of the edges of the leaves later in the season, more common on some varieties, *e. g.*, the Sheldon, than on others, and so on. But the real blight kills the limb in advance of the leaves, and will usually show the blackened bark, when raised with a knife, below the lowest dead leaves; the gummy exudation, when that is to be found, is abundant confirmation. In addition to this, the extent of the malady, sometimes embracing the larger part of the tree and most of the trees of the orchard, assures one of its identity. Pear leaves may at times assume a deeply bronzed appearance and the bark become dark colored, but these appearances need never be mistaken for blight, as the tissues beneath will be found normally green and healthy.

The disease is most observed during July and August. It may manifest itself upon any part of the tree, but starts rather more often at the ends of the main branches, and will first attract attention by the dead leaves. All above the affected parts will usually die, and if the branch is not removed the disease will gradually extend toward the trunk of the tree. It is purely a local disease,

and affects no part of the tree but the branches attacked. Sometimes a whole tree is killed, but usually only certain limbs die, which if early removed will leave the remainder of the tree in normal condition. The progress of the disease along the limb is variable, but in general is greatest during the hottest weather; in winter it moves slowly, even advancing but six to twelve inches during a whole cold season. The advent of spring, quite contrary to what one would expect, usually checks the disease after it has defied the rigors of winter, and by the time the tree is well clothed with leaves is brought to an end, not to be again revived.

So extensive and prominent a disease of an important fruit tree, and one entailing heavy pecuniary losses during epidemic years, has naturally been the occasion of much discussion. Its cause being obscure and the manner of its incursions and spread mysterious, it was variously ascribed to the soil, the weather, the electrical influences of thunder storms, to undiscovered fungi, and many other agents. These attempts at explanation were all unsatisfactory, failing to account for many of the phenomena connected with the disease.

The first substantial advance toward a solution of the question was made by Dr. T. J. Burrill in his memorable announcement in 1880 to the American Association for the Advancement of Science that he had discovered bacteria in invariable connection with the disease. The same discovery was reiterated by the author in an article in this magazine for July, 1881. He also proved that the disease is infectious and may be communicated to healthy limbs by inoculation, using the gummy exudation as a virus either with or without dilution with water, and not only to pears but to apples and quinces as well.

No additional discoveries of note were made till the investigation, which is still continued, was taken up by the writer in July, 1884. The subject need not be further treated chronologically, as a clearer and more concise statement can be made by giving the present condition of our knowledge irrespective of the order of its acquisition.

The term bacteria is a generic one, and covers many forms exhibiting great morphological and physiological differences. The form causing pear blight does not belong to the genus Bacterium, as one might infer, but to the genus Micrococcus, and bears the

full name of *M. amyliovorus* Burrill. Members of this genus are globular, or somewhat longer than broad, either single or in short chains of a few individuals; they multiply by a transverse division, each half growing to the size of the original from which it was derived, and finally becoming an independent cell. The formation of spores does not occur, or at least has not been discovered, in this genus; no transformation takes place.

The pear blight Micrococcus is oval in outline and measures 1 by 1½μ, which is .00004 by .00006 inch. This is extremely small, so small, in fact, that it would take more than a thousand placed end to end to reach around the period at the close of this line. They are considerably smaller than the bacteria of common putrefaction (*Bacterium termo*), the hay bacteria (*Bacillus subtilis*) which usually appear in all sorts of vegetable infusions, and many others. On the other hand they are by no means so small as the germs of diphtheria (*Streptococcus aiphtheriticus*), of small-pox (*S. vaccinæ*), and others. When in active growth they are single or attached to each other in pairs, dumb-bell form; when growing more slowly there is a larger proportion of the dumb-bells, and in addition chains of four to six cells each.

Although these bacteria are very small, yet there is no difficulty in demonstrating them in the tissues of the pear tree on account of their extraordinary abundance. The slightest fragment taken in midsummer from a blighted pear limb and placed in a drop of water will readily enough show the presence of bacteria to the unaided eye by the white cloud of them which spreads from the bit of wood throughout the water. Slice up some blighted wood into a small quantity of water and it will be rendered milky by the enormous outpouring of the bacteria. Under the microscope these are found to be all of one kind, and not intermixed with ordinary putrefactive or other bacteria, a circumstance which may yet be turned to account in studying problems in which an admixture of forms is detrimental. The exudation already referred to is found by the microscope to be composed solely of blight bacteria and a soluble substance which holds them together.

When in very vigorous growth the blight bacteria are active, and present an animated appearance under the microscope, but usually they have only the molecular movement common to all small particles suspended in fluid. Their progress through the

plant is doubtless largely due to simple displacement as multiplication takes place, although aided by the limited activity of the organism and the movement of the sap.

The change induced in the tissues of the tree partakes of the nature of a true fermentation. That we do not have to do with a putrefactive change is patent enough, as no offensive odor is given off. The disengagement of carbon dioxide may be made evident by partially filling a test tube with fragments of a freshly blighted limb and adding water enough to little more than cover them. In a short time bubbles of gas will be set free, and a drop of lime water held in the tube will show the presence of carbon dioxide by the whitening of its surface. It is not so easy to determine the nature of the other products formed. Careful and repeated tests give no indication of the occurrence of butyric acid. The presence of alcohol in very slight amount was shown by means of the delicate iodoform test. For this a nearly full-grown Bartlett pear, which was thoroughly permeated with the blight bacteria from an inoculation made a week before, but the tissues still undiscolored, was distilled and the distillate used for the test. The amount of alcohol found was so slight, however, requiring a microscope to find the crystals produced by the test, that it did not account for the main bulk of the product of the organism's activity. This product is presumed to be mainly gum of some sort, for the following reasons, *inter alia:* the solubility, adhesiveness, taste or rather tastelessness and the appearance upon drying. There is much probability, indeed, that this belongs to the viscid fermentations, which have been but little investigated.

The bacteria in the tree first attack the starch of the cells, then the cellulose of the cell walls, and finally the whole tissue becomes a liquid mass. When, however, the cell walls consist of lignin or other secondary substances they are not broken down. The action on the cell wall is best seen in the tender, unmodified tissues of the fruit.

After this survey of the characteristics of the organism and the chemical changes which it induces, it will be profitable to learn something of the nature of the disease itself. The usual impression has been that the disease is like a blast of superheated air passing over an orchard, leaving dead and blackened foliage in its track, or that it appears suddenly as the result of a thunder

storm following hot and damp weather. Its true nature, so different from these conceptions, has been learned by inoculating healthy limbs with germs from an affected tree and closely watching the progress of the disease through its whole course from inception to the death of the limb. The inoculation is made by puncturing the limb and applying some of the gummy exudation, or, better, a drop from a watery solution of it, or from water in which some diseased tissue has been sliced. If this be done in July and the inoculation be made in a young and tender shoot, the tissues near the wound will show discoloration in about a week, and in the course of a week longer the leaves and end of the shoot become blackened and dead. Let it be noticed that at the most favorable season for development it requires some two weeks from the time of the attack to enable the disease to gather sufficient headway to be conspicuous; for no observer is likely to detect the change in the color of the bark before the dying leaves have fixed his attention, unless he knows an artificial inoculation has been performed. This sufficiently disposes of the supposition that the disease is sudden in its action; still more marked proof will be adduced later, showing that in natural course it is slower yet. Over two hundred recorded inoculations have been made, and from these we learn that the disease makes the most rapid progress in the newest and most succulent tissues; and the nearer to a vigorously growing bud an inoculation is made, the more likely it is to succeed. In fact, it was soon found that no result was likely to follow an inoculation in wood a year or more old. This suggested the inoculation of growing fruit; the results were most surprising, for the tender parenchymatous tissues were entirely broken down into a creamy fluid, which now and then escaped at the wound made in inoculating and dripped upon the ground.

Repeated attempts to convey the disease by inoculating the leaves resulted in failure, except a partial success when very young leaves were tried. It is noticeable that the leaves are the last to succumb to the disease; they will remain green for days or even weeks after the bark at that point has become brown and dead. Bacteria cannot be found swarming in the leaves as in the bark and wood; the conditions do not seem favorable for their development. The conclusion is inevitable that the death of the leaves on a diseased branch is chiefly due to the cutting off of the supply of sap.

The investigations of Professor Burrill showed that the disease might be conveyed to the apple and quince trees also. Not only was this easily confirmed, but inoculations were successfully performed on the English hawthorn (*Cratægus oxyacantha*), the evergreen thorn (*C. pyracantha*), and the service berry (*Amelanchier canadensis*), while they failed on grape, raspberry, mulberry, peach, etc.; that is, they succeeded on members of the pear family, but not on other plants. The virus was from the pear, apple and quince, interchangeably, and showing no perceptible difference in the results that could be traced to the kind of virus used. The only differences to be noted were such as were obviously accounted for by the varying ripeness and solidity of the tissues. Unsuccessful inoculation was made upon the mountain ash (*Pyrus aucuparia*), but as the tissues were already solid when done, and as branches suffering with the disease have since been found, there is no doubt that it can be communicated if the inoculation be properly performed.

In the studies so far detailed the germs were artificially introduced into the branch; the problem of how they gain entrance naturally seemed for a time well nigh unsolvable. Virus smeared upon the outside of the branch, leaf or fruit had no effect; diseased branches tied among healthy ones under the most favorable circumstances for contagion gave no results; apparatus arranged to draw air across diseased branches upon healthy ones also failed; copiously watering a potted pear tree for a month with water white with blight bacteria had no deleterious action on the tree; and yet the germs must gain entrance some way, for it is inconceivable that they should originate spontaneously within the tree. Finally some light was secured by a series of partially successful experiments in which water containing blight bacteria was arranged to drip upon pear and apple twigs; the germs entered the twigs through the moist surface of the youngest tissues. A fortuitous observation now made the matter clear; it was noticed toward the end of June that the English hawthorns, which blossom very freely about the middle of May, were seriously affected with blight. At the time of observation the flowers had long since disappeared and the fruit was well advanced toward maturity. The blighted branches, however, were still crowned with dead flowers, and wherever the dead spur or branch was not terminated with a truss of flowers it showed

every evidence of having been arrested in the midst of rapid growth. The conviction was established that the germs enter the tree in spring through the moist glandular surfaces within the flower or the tender surfaces of expanding buds, but that the disease does not make sufficient progress to become conspicuous till the warm days of June or July. As the flowers drop and the branches cease extending less and less chance exists for the tree to take the disease. Insects may now and then transfer the germs, for two pears were found the present season filled with blight, in both cases showing the point of entrance, evidently a puncture made by an insect. It is only in some such exceptional way that the germs can gain admittance through the well protected surface of fruit.

If the germs pass from the air into the tree, in what manner do they get out into the air again at the proper time for the next season's attack? Manifestly the bacteria within the tree are securely imprisoned by the bark, which as effectually prevents their escape as it does their entrance; and at any rate, in spring, the time for attack, there are few bacteria left alive in the tree. Limbs with tender tissues exude great numbers of germs during July and August, but so agglutinated that the air cannot dislodge them, until the rains have washed them to the ground and dissolved the gum which binds them together. The query now presents itself whether the germs may not be able to thrive outside the tree. To test this, cultures were tried in various media, and it was found that infusions of hay, corn meal, starch and various other vegetable substances make a nutritive fluid in which the blight bacteria flourished in varying degrees, no matter whether the solutions were acid, alkaline or neutral. When transferred from the culture fluid to the tissues of the tree, the usual form of blight follows. This plainly indicates that the germs washed from the tree by rain may find congenial nidus among vegetable refuse, thrive and multiply, pass the winter, for cold does not injure them, even pass an unfavorable year or two, and at times being swept into the air be brought by gentle rains or an arresting film of dew into contact with the delicate surfaces of expanding shoot or flower and infection be secured.

Now having shown the progress of the disease to be coördinated with the development of germs and traced the life cycle of the germs, there may still be persons who do not believe that

germs cause the disease, but that they are merely accompaniments of it. To meet this objection, and place the subject upon a logical and irrefragible basis it is necessary to state the results of still further studies. In order to determine whether other bacteria will grow under the same circumstances, various kinds were inoculated into pear trees—bacteria from rotting spots in green tomatoes, from various sorts of putrefactions, those which had incidentally appeared in various culture experiments—and uniformly with negative results. When inoculation was made from a culture of blight bacteria contaminated with other forms, the resulting blight contained but the one sort. It is a well-known fact that most bacteria will not thrive in acid solutions, and Hartig has supposed that the reason that plants are so free from parasitic bacteria (only two, or at the most three, true vegetable parasites being known among them) is that they cannot withstand the acidity of the sap. Be this as it may, only one form of bacteria has yet been found to accompany pear blight.

But this does not dispose of the possibility that the blight is not caused by the bacteria, but by some deleterious substance which goes with them or which they produce. It is obvious that as the blight may be produced by using a drop of water which has been flowed over blighted tissues, the active agent must be either the bacteria or the substances which the water dissolves. There is a very simple way of separating solutions from bacteria by filtering through porous earthenware, which permits the fluid to pass, but not the bacteria. It has been demonstrated by trial that inoculating from a filtrate prepared in this way will not produce the blight. Separating the bacteria from all accompanying substances is accomplished by means of fractional cultures. Such a drop as used for inoculating is introduced into a suitable sterilized culture fluid; after some days, when the bacteria have well filled it, a drop is removed and used to start another culture, and so on. In this way the bacteria are kept vigorous by growth and multiplication, and the unvitalized substances which accompanied them in the first drop are more and more diluted at each transfer. Finally a drop from the last culture of the series, in which the amount of substance derived from the original drop must be so infinitesimally small as to be inoperative, is used to inoculate with again. Carefully conducted experiments of this kind have given as severe blight as in direct inoculation. No stronger proof is needed that the bacteria are solely responsible for the disease.